A deep sky survey at 7.6 cm with the RATAN-600 radio telescope

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Preliminary results are reported on the behavior of the curve for the integrated number of radio sources against limiting flux density in the low-flux range ($P > 0.86$ mJy), as determined from observations at 7.6-cm wavelength with the RATAN-600. The radiometer was equipped with a broad-band parametric amplifier cooled to 15 °K. At a level $P \approx 1$ mJy the surface density of radio sources is $\approx 2 \times 10^5$ sr^{-1}, or ≈ 100 times lower than would be expected for a static Euclidean universe.

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1. INTRODUCTION

During March–May 1980 the narrow strip of sky bounded by coordinates $0^h < \alpha < 24^h$, $+4°44' < \delta < 4°54'$ was observed with the RATAN-600 radio telescope at a wavelength of 7.6 cm. A new type of radiometer was used at this wavelength; it has a 0.5-GHz passband and the input stage is cooled with helium vapor by a closed-cycle machine to 15 °K. The observations were made by allowing the strip of sky to drift across the stationary telescope beam. At half-power level the beam measured $0'.9 \times 10'$ in right ascension and declination, respectively. The effective area of the radio telescope was 1050 m^2.

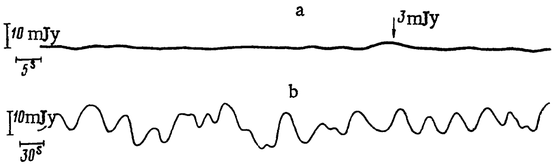

FIG. 1. A comparison between the sensitivity of: a) the present Zelenchukskaya survey; b) a deep survey at $\lambda = 6$ cm with the 100-m Effelsberg radio telescope.[1] The traces represent scans of the sky by the beams of these two telescopes; the regions differ, but fields free of strong sources have been selected. The rms sensitivity of the surveys with respect to flux density is: a) $\Delta P_{rms} \leq 0.6$ mJy; b) $\Delta P_{rms} = 3$ mJy.

Measures were taken to mitigate the influence of terrestrial interference, and as a result the system noise temperature was held to 38 °K. The radiometer therefore achieved the high sensitivity of 2–2.5 mK for a time constant $\tau = 1$ sec, corresponding to a flux-density sensitivity of ≈ 6 mJy. We report here some preliminary results on the statistics of radio sources having a flux density $P > 0.86$ mJy.

2. RESULTS OF OBSERVATIONS

Figures 1–5 display sample individual and averaged records of the sky radio emission at 7.6 cm. These traces illustrate the profiles obtained for various sources that came within the telescope field of view. The sensitivity of this survey surpasses that of all sky surveys hitherto published (if one adopts a standard spectral index $\alpha \approx 0.75$ to reduce all flux densities to $\lambda = 7.6$ cm). About 30 diurnal traces were recorded, and when these are averaged one can discern sources as weak as ≈ 1 mJy. As a rule

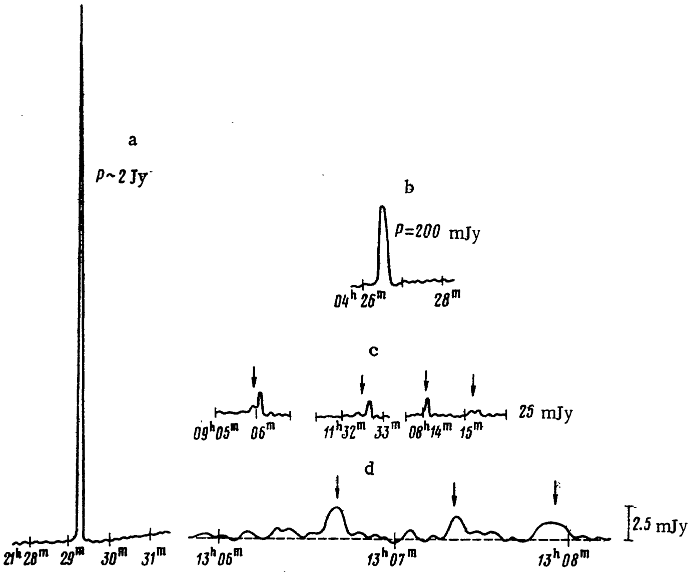

FIG. 2. Sample traces of various radio sources detectable in the individual diurnal traces: a) the strongest source encountered in the deep survey, PKS 2127 + 04; b) one of the weakest sources in the Parkes survey, PKS 0425 + 04; c) some typical new sources (there are about 500 of them on each diurnal trace); d) a portion of the record after all 36 diurnal cycles of observation were averaged. The right ascensions are referred to epoch 1980.3.

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TABLE I. Completeness of Survey

Flux density, mJy	Completeness	Flux density, mJy	Completeness
0.5	0.5	2.0	0.995
0.8	0.75	3	>0.999
1.0	0.85	5	>0.999
1.5	0.96	10	>0.999

TABLE II. Source Counts in a Sample Field

Flux-density interval, mJy	Number of sources		Flux-density interval, mJy	Number of sources	
	uncorrected	corrected for completeness		uncorrected	corrected for completeness
0.86—1.14	27	(7)	2.28—2.8	17	17
1.14—1.7	28	17	2.8—3.99	17	17
1.7—2.28	16	15	3.99—5.7	10	10

TABLE III. Integrated Source Counts in Sample Field

Flux density P_0	Number of sources, $N(P > P_0)$		$\log N$, sr^{-1}
	observed	corrected for completeness	
0.86	125	93	5.22
1.14	98	86	5.19
1.7	70	69	5.09
2.28	54	54	4.99
2.8	37	37	4.82
3.99	20	20	4.55
5.7	10	10	4.25

TABLE IV. Integrated Counts of Strong Sources

Flux density P_0	Number of sources, $N(P > P_0)$	$\log N$, sr^{-1}
7.5	(480)	4.51
25	179	4.08
50	86	3.77
75	50	3.53
125	27	3.27
250	9	2.79
750	(2)	2.2

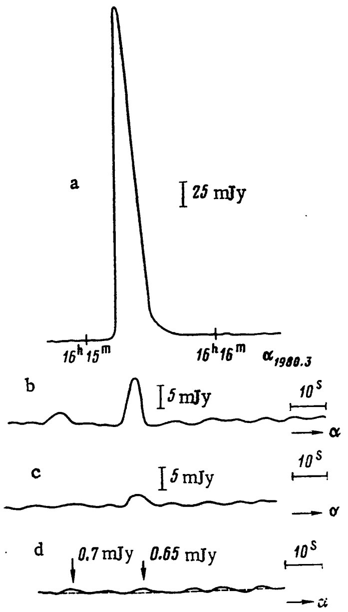

FIG. 3. Sample profiles of individual sources after averaging of the 36 diurnal cycles: a) a previously catalogued source, OS +0.23; b,c) typical new, weak sources; d) an "empty" section, showing only sources at the limit of sensitivity. The reality of the sources marked by arrows has been verified by comparing the results of two independent series of observations, each covering many diurnal cycles.

we have found all radio sources that have previously been detected at any wavelength, except that a large percentage of the weak sources in the Ohio catalog are missing from our traces, perhaps because of the large uncertainty in the coordinates of the weak Ohio sources. This situation is exemplified by Fig. 5a. The flux densities to be expected at 7.6 cm from the sources marked in this figure would have been ≈100 mJy.

To estimate the fluctuation sensitivity of the radio telescope with regard to flux density we have divided the whole series of observations into two groups, in an effort to circumvent the influence of discrete radio sources; the averaged drift curve for the second group of observations was then subtracted from that for the first group. With a 3.6-sec effective integration time in the diurnal records, the sensitivity obtained in this way for a drift curve averaged over 24 days is 0.64 mJy. This sensitivity compares with a value of ≈6 mJy in an individual trace with τ = 1 sec, or ≈3 mJy for an integration time about the same as the time required for a radio source to drift across the stationary beam. Using this value for the dispersion we have estimated the completeness of the survey at selected flux-density levels (Table I).

We conclude that the survey is quite complete for the as yet unstudied flux-density range P = 1–10 mJy; for stronger sources the completeness is virtually perfect.

In Table II we take one portion of the strip, $13^h < \alpha < 14^h$, and give the number of sources observed in different flux-density intervals without and with correction for the completeness of the survey. On the basis of Table II we can find the number of sources whose flux density exceeds a given value (Table III).

Table IV gives the distribution of sources with a flux

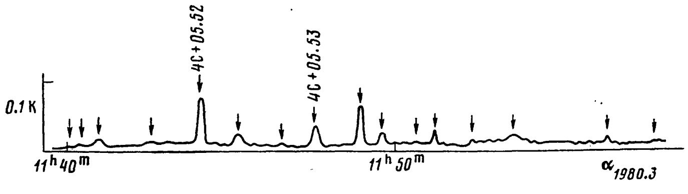

FIG. 4. A portion of a diurnal trace that is heavily saturated with sources. The arrows mark objects that repeat from day to day.

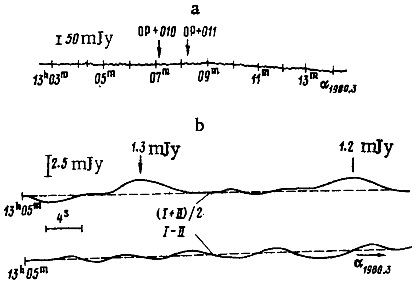

FIG. 5. a) An empty section of a diurnal trace (the arrows mark the position of two Ohio catalog sources; b) the result obtained when two independent series of measurements of this region, each averaged over many days, are combined and subtracted.

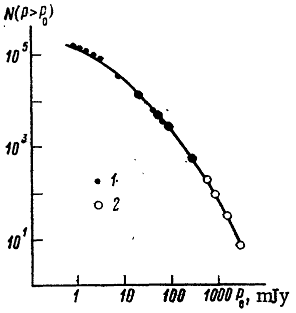

FIG. 6. Number of radio sources as a function of flux density [the (log N, log P) diagram]. 1) The RATAN-600 data; 2) results of the latest survey with the 100-m Effelsberg paraboloid.

density P > 7.5 mJy, as determined from inspection of the individual diurnal records throughout the strip $0^h < \alpha < 24^h$.

In Fig. 6 we have plotted the curve for the number of sources against flux density. The curve includes the data in catalogs of "strong" and "weak" radio sources as well as the results of the deep survey reaching limiting sensitivity that was carried out at Bonn.[1] Notice that the (log N, log P) curve fits the Bonn data perfectly for the range of flux densities in common, but its behavior undergoes a sharp change for very weak sources, tending to become "saturated" at a level of $2 \cdot 10^5$ sources/sr.

3. DISCUSSION

One may draw two conclusions from Fig. 6:

1. At centimeter wavelengths the number–flux density curve continues to flatten out in the flux-density range from 10 to 0.86 mJy. The smoothness of the curve suggests that, at least in the $13^h < \alpha < 14^h$ field that was investigated, the range of low flux densities mentioned above evidently contains no new population of radio sources. This result conflicts with the findings of Wall[2] and Ledden et al.,[3] which rely not on direct source counts but on statistical estimates for the density of sources (more than one source) within the radio telescope beam. We have observed several times fewer sources than estimated by Ledden et al., and 10 times fewer than predicted by Wall.

2. Our number–flux density curve is in good agreement not only with the Bonn survey[1] at a nearby wavelength for the range P > 15 mJy, but also with the results of deep 408-MHz surveys carried out at Cambridge. Pooley and Ryle[4] have published information on the statistics of the 408-MHz sources whose flux density is above 15 mJy. If such sources have a standard spectrum ($\alpha \approx 0.75$) their flux density at $\lambda = 7.6$ cm would be ≈3 mJy. Thus the consistency of our number–flux density curve with Pooley and Ryle's results indicates that the curve is independent of frequency, at least in the flux-density range $3 < P < 100$ mJy. For sources with $0.86 < P < 3$ mJy, however, our measurements have thus far been made only at 7.6 cm, so the frequency dependence of this part of the (log N, log P) curve cannot yet be assessed.

[1] I. I. K. Pauliny-Toth, A. Witzel, E. Preuss, J. E. Baldwin, and R. E. Hills, "A deep 4.85-GHz survey of a region near the North Celestial Pole," Astron. Astrophys. Suppl. 34, 253-258 (1978).

[2] J. V. Wall, "An estimate of the counts of faint radio sources at 5 GHz," Mon. Not. R. Astron. Soc. 182, 381-393 (1978).

[3] J. E. Ledden, J. J. Broderick, J. J. Condon, and R. L. Brown, "A confusion-limited extragalactic source survey at 4.755 GHz," Astron. J. 85, 780-788 (1980).

[4] G. G. Pooley and M. Ryle, "The extension of the number–flux density relation to very small flux densities," Mon. Not. R. Astron. Soc. 139, 515-528 (1968).

Interstellar hydroxyl near Sagittarius B2

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The 1665-, 1667-MHz OH absorption lines near the radio source Sgr B2 have been observed with the RATAN-600 radio telescope at 2'.2×47'×5.4 km/sec resolution. Physical parameters are determined for the five OH clouds observed in this direction at positive radial velocities. Evidently only one of these clouds can have any connection with the Sgr B2 source; it is located at the edge of the gas envelope surrounding that source.

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The radio source Sagittarius B2 is a strong complex of gas and dust situated in the neighborhood of the galactic center. Many different authors have investigated the structure of this source in the continuous spectrum, in recombination radio lines, and in the lines of molecules and neutral hydrogen. The subject has been reviewed by Scoville et al.[1] and by Oort,[2] where further references will be found. In a recent letter[3] several of us have described a study of the kinematics of the H I cloud that is associated with the source. We concluded that Sgr B2 is embedded in an H I envelope of our radius ≈20 pc which is rotating at a speed of ≈20 km/sec at its periphery in the same sense as the galactic rotation.

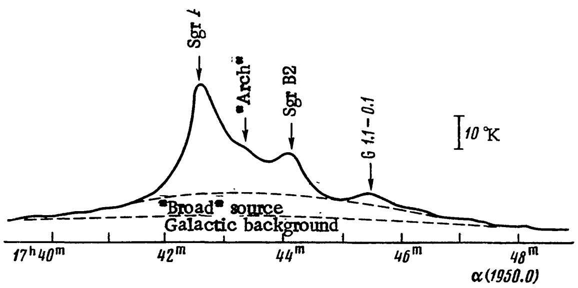

FIG. 1. A drift curve for the source Sagittarius B2 at 18-cm wavelength.

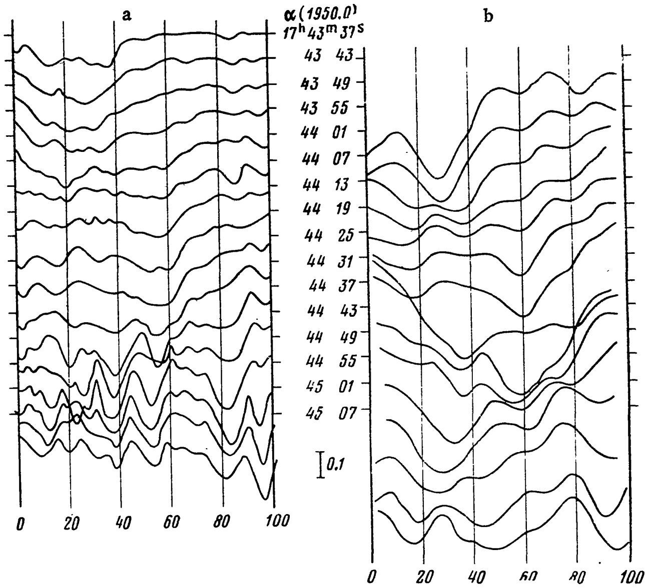

FIG. 2. Relative OH absorption profiles at: a) 1665 MHz; b) 1667 MHz. Horizontal dashes indicate the zero-level of each profile, recorded at the right ascension specified.

There has been comparatively little study of the interstellar hydroxyl in Sgr B2. Cohen and Few[4] have measured the OH distribution at frequencies of 1665 and 1667 MHz with 11' angular resolution. Bieging[5] has used an aperture-synthesis system to survey the OH distribution in the 1667-MHz line at 3'.25 resolution. We present in this letter the results of our observations of this source in the 1665- and 1667-MHz OH lines, as carried out with the RATAN-600 radio telescope in the Causcasus with a still higher resolution in one coordinate.

Elsewhere we have described the observing procedure and the radio spectrometer.[6] The system noise temperature at 18-cm wavelength was 180 °K. The halfwidth of the antenna beam measured 2'.2 × 47', and the resolution in radial velocity was 5.4 km/sec. Drift curves of the source in the radial-velocity range from −3.2 to +102 km/sec were obtained at 2.7-km/sec intervals. The error in measuring the antenna temperature at 1665 MHz, after three tracings were averaged, was 0.5°K in the spectral channels and 0.03°K in the continuum channel. At 1667 MHz the sensitivity was found to have deteriorated by a factor of 1.5.

Figure 1 displays the drift curve of the radio source Sgr B2 recorded at $\delta = -28°21'24"$ in the continuum channel. The principal objects observed in this region are marked. Since the antenna pattern was comparatively broad in declination, it is hard to discriminate Sgr B2 from the weaker source G0.5 −0.1 located to the southwest. We discuss below the results of our observations, which refer only to the source Sgr B2 at positive radial velocities.

The $\Delta T/T_C$ profiles of the relative OH absorption are presented in Fig. 2 for the (left) 1665-MHz and (right) 1667-MHz lines. Here T_C denotes the antenna temperature of the source in the continuum, measured relative to the galactic background level (Fig. 1). The profiles have been smoothed in radial velocity, so that the resultant resolution is 7.7 km/sec at 1665 MHz and 10 km/sec at 1667 MHz. The radiation of the "arch," the source G0.2 −0.5, has been excluded from T_C, because this source

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